Fixed Bed Pyrolysis of pulm seed Waste for Liquid Oil Production

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ABSTRACT

Among various thermo-chemical conversion processes, pyrolysis is considered as an emerging technology for liquid oil production. The conversion of biomass waste in the form of plum seed into pyrolysis oil by fixed bed pyrolysis reactor has been taken into consideration in this study. A fixed bed pyrolysis has been designed and fabricated for obtaining liquid fuel from this plum seeds. The major component of the system are fixed bed pyrolysis reactor, liquid condenser and liquid collectors. The plum seed in particle form is pyrolysed in an externally heated 7.6 cm diameter and 46 cm high fixed bed reactor with nitrogen as the carrier gas. The reactor is heated by means of a biomass source cylindrical heater from 400^0C to 600^0C. The products are oil, char and gas. The reactor bed temperature, running time and feed particle size are considered as process parameters. The parameters are found to influence the product yield significantly. A maximum liquid yield of 39 wt% of biomass feed is obtained with particle size of 2.36-4.75 mm at a reactor bed temperature of 520^oC with a running time of 120 minutes. The pyrolysis oil obtained at this optimum process conditions are analyzed for some fuel properties and compared with some other biomass derived pyrolysis oils and conventional fuels. The oil is found to possess favorable flash point and reasonable density and viscosity. The higher calorific value is found to be 22.39 MJ/kg which is higher than other biomass derived pyrolysis oils.

Keywords: Renewable energy; Pyrolysis oil; Fixed bed; Plum seeds

1.0 INTRODUCTION

Biomass has been recognized as a major renewable energy source to supplement declining fossil fuel sources of energy [1]. It is the most popular form of renewable energy and currently biofuel production is becoming very much promising [2]. Transformation of energy into useful and sustainable forms that can fulfill and suit the needs and requirements of human beings in the best possible way is the common concern of the scientists, engineers and technologists. From the view point of energy transformation, pyrolysis is more attractive among various thermochemical conversion processes because of its simplicity and higher conversion capability of biomass and its solid wastes into liquid product. Pyrolysis is generally described as the thermal decomposition of the organic components in biomass wastes in absence of oxygen at mediate temperature (about 500° C) to yield tar (bio oil, bio fuel, bio crude), char (charcoal) and gaseous fractions (fuel gases). Pyrolysis may be either fixed bed pyrolysis or fluidized bed pyrolysis. In fixed bed pyrolysis, a fixed bed pyrolyser is used. The feed material in the reactor is fixed and heated at high temperature. As the feed is fixed in the reaction bed (reactor), it is called fixed bed pyrolysis. In this process, the feed material is fed into the reactor and heat is applied externally. Usually nitrogen is used as inert gas for making inert condition and for helping the gaseous mixture to dispose of the reactor. The losses in fixed bed pyrolysis are relatively less than fluidized bed pyrolysis. A possible reaction pathway of pyrolysis process is shown in Figure 1. This technology is spreading with research and experimental work in many countries of the present world [3]. Energy is the major requirement of modern society, its development and management carries a lot of significance in the economic development of any country. There is a close relationship between the level of energy consumption in a country and its economic development. The energy consumption in the world has been growing at an alarming rate. By the year 2100, the world population is expected to be more than 12 billion and it is estimated that the demand for energy would increase by five times the current demand [4]. Under such circumstances, man has to find out

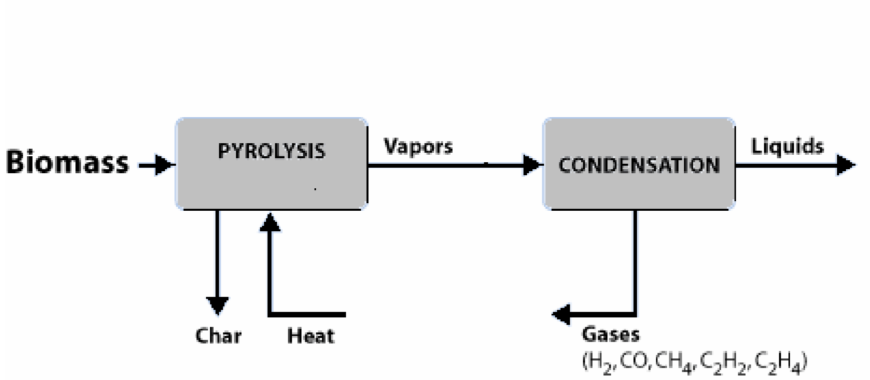

Figure 1**:** A possible reaction pathway of pyrolysis of organic solid waste

some sources of energy for his survival to be able to meet considerable part of the energy demand in future. In this contest, fixed bed pyrolysis system from the plum seed is one of the promising sources of energy. This carboneous solid waste is renewable energy source and therefore the potential of converting this into useful energy such as liquid fuel should be seriously considered. In this way, the waste would be more readily usable and environmentally more acceptable This waste may be used for energy recovery as fuel. The pyrolysis oil is of moderate heating value, is easily transported, can be burnt directly in the thermal power plant, can possibly be injected into the flow of a conventional petroleum refinery, burnt in a gas turbine or upgraded to obtain light hydrocarbons for transport fuel [5]. Besides these, there are scopes to upgrade the oil to obtain high grade fuel and valuable chemicals. The solid char can be used for making activated carbon. The char has its potential as a solid fuel [5].

2. 0 MATERIALS AND METHODS

2.1 MATERIAL

Bangladesh, India, Nepal, Pakistan and Bhutan are agriculture-based countries. Plum (*Zyziphus jujuba*) is one of the major fruits of these countries. In 1997-98 about 15 thousand metric tons of plums are produced in Bangladesh. About 25-40 wt% of plum is its seed. Plum seed was collected locally at Rajshahi, Bangladesh. It was ground and sieved to different feedstock of sizes 2.36-4.75 mm, 4.75-6.35 mm and 6.35-9.53 mm. The feedstock was oven dried for 12 hr at 110^{o}C prior to pyrolysis.

2.2 EXPERIMENTAL SETUP

Plum seed is pyrolyzed in an externally heated stainless steel fixed bed reactor system. The main components of the system are fixed bed reactor, liquid condenser and ice cooled liquid collectors. The effective length of the reactor is 46 cm and the diameter is 7.60 cm. The schematic diagram of the fixed bed pyrolysis system is shown in Figure 2. The reactor is heated externally by a biomass heater at different temperatures (400, 450, 500, 550 and 600^{0}C) and the temperature is measured by means of a mercury thermometer. Nitrogen gas is supplied in order to maintain the inert atmosphere in the reactor, and to dispose of the pyrolyzed vapor products to the condenser. Pyrolysis vapor is condensed into liquid in the condenser and then it is collected in the liquid collectors. The non-condensed gas is flared to the atmosphere.

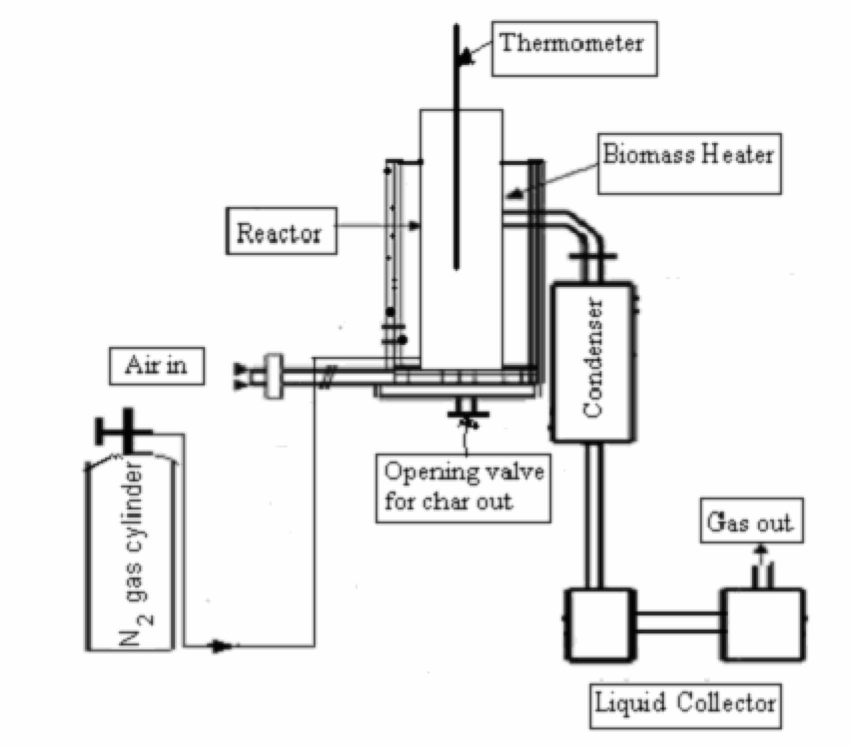

Figure 2: Schematic diagram of fixed bed pyrolysis system

3.0 RESULT AND DISCUSSION

3.1 PRODUCT YIELD

The products obtained from the pyrolysis of plum seed are liquid oil, solid char and gas. At an operating temperature of 520 ^{0}C for a feed size volume of 2.36-4.75 mm at a gas flow rate of 8 liter/min with a running time of 120 minute, liquid production is found to be the maximum (39 wt%) of the dry feedstock.

3.2 EFFECT OF OPERATING TEMPERATURE

The relationship between the variation of percentage of mass of liquid, char, and gaseous products at different reactor bed temperature is presented in Figure 3. The results show that as the operating temperature is increased, the liquid yield is increased up to 520 ^{0}C at a liquid yield of 39 wt%. After this temperature, the liquid yield decreased. At a lower temperature of 440 ^{0}C, the liquid product is found to be 28 wt% of the dry feedstock. The higher temperature above 520^0 C may cause secondary cracking reaction of the vapors, yielding more gas at the cost of liquid product. On the other hand the reason for the lower liquid yield at lower temperature may be due to fact that the temperature is not enough for complete pyrolysis to take place.

3.3 EFFECT OF FEED PARTICLE SIZE

Figure 4 represents the percentage mass of liquid and solid char products for different feed particle size of feed at a bed temperature of 520 ^{0}C and an operating time of 120 minutes. It is observed that at 520 ^{0}C the percentage of liquid collection is maximum at 39% of total biomass feed for particle size volume of 2.36-4.75 mm. Liquid yield is found to be maximum for the smaller particles because the larger size particles might not be adequately heated up so rapidly causing incomplete pyrolysis.

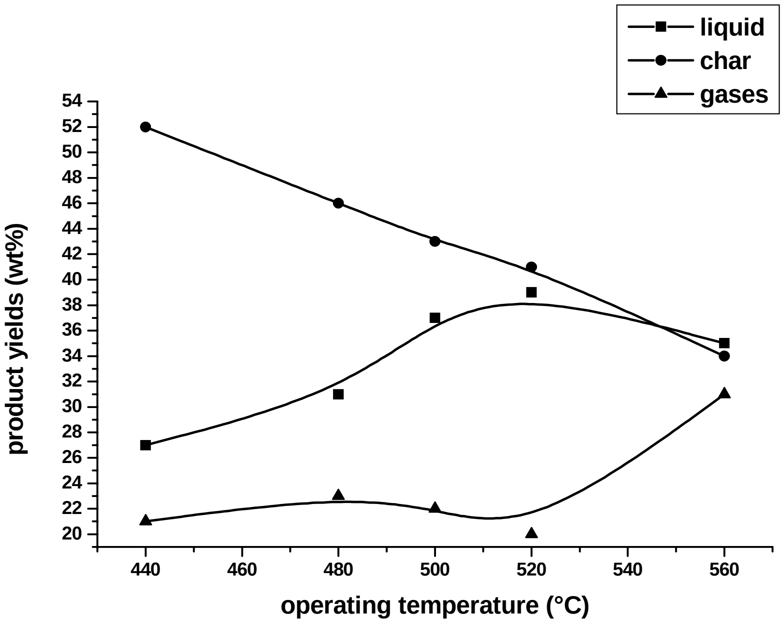

Figure 3: Effect of operation temperature on product yield.

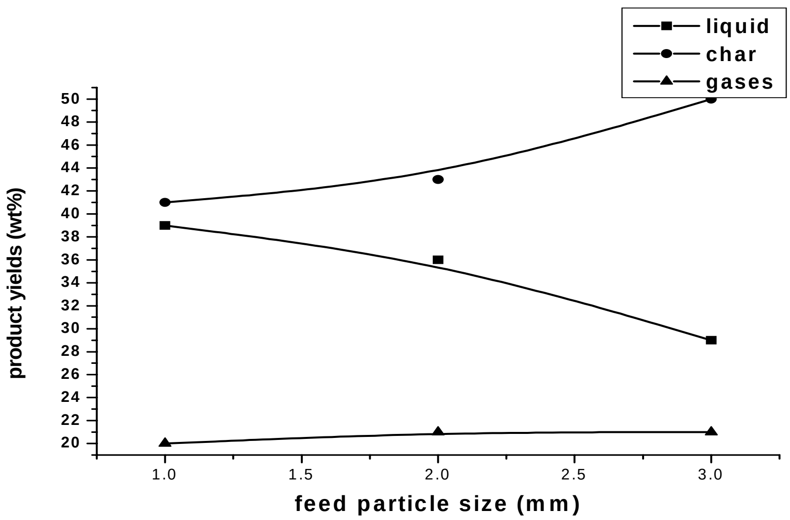

Figure 4: Effect of feed particle size on product yields.

3.4 EFFECT OF RUNNING TIME

The effect of variation of running time on product yield is presented in Figure 5 at a temperature of 520 ^{0}C and for feed particle size volume of 2.36-4.75 mm. The plotted result shows that the liquid yield increases with the increase of running time. The maximum liquid product is found to be 39 wt% of biomass feed while the solid char product is 41 wt% of dry feed at 120 minutes. After this, the liquid product yield is not optimum that may be due to complete devolatilization of the feedstock and higher rate of gas discharge.

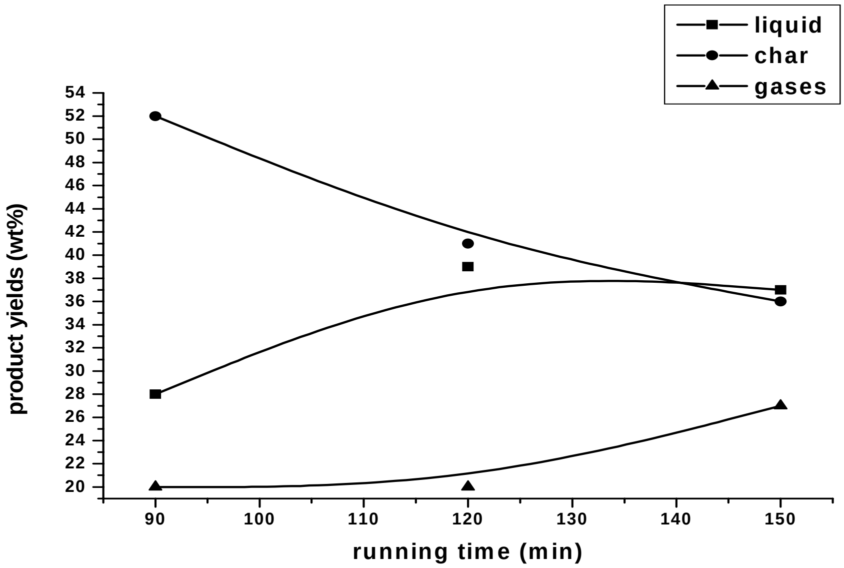

Figure 5: Effect of running time on product yield

4.0 ANALYSIS OF PYROLYSIS OIL

4.1 PHYSICAL PROPERTY ANALYSIS OF PYROLYSIS OIL

The energy content of the oil is found to be 22.39 MJ/kg. The oil is found to be slightly heavier than diesel with a density of 940 kg/m^3 at 30^{0}C. The flash point of the oil is 112 ^{0}C and hence extra precautions are not required in handling and storage at normal atmosphere. The low viscosity of the oil of 1.14 cSt at 30 ^{0}C is a favorable feature in handling and transportation.

4.2 COMPARISON WITH OTHER BIOMASS DERIVED OIL AND DIESEL FUEL

Table 2 shows the characteristics of the pyrolysis oil derived from plum seed in comparison with other biomass derived oils and diesel fuel. It is evident that the density and viscosity of plum seed oil is favorable than other pyrolysis oils and very much closer to diesel. The higher heating value of plum seed oil is found to be higher than other biomass derived oil.

Table 1: Comparison of plum seed pyrolysis oil with other biomass derived oils and diesel fuel.

Analysis	**Plum Seed oil**	**Waste paper oil** [6]	**Sugarcane bagasse oil** [7]	**Jute stick oil** [7]	**Diesel** [8]
Kinematic viscosity at 30^{0}C (cSt)	1.14	2.00	13.80	12.08	2.61 at 20^{0}C
Density (kg/m^3)	940	1205	1160	1224	827.1
Flash Point (^{0}C)	112	200	105	>70	53
HHV(MJ/kg)	22.39	13.10	20.072	21.091	45.18
pH value	3.19	1.5	2.98	2.92	-

5.0 CONCLUSION

The biomass solid waste in the form of plum seed is successfully converted into liquid, char and gas by fixed bed pyrolysis system. The heating value of the pyrolysis oil is found to be 22.39 MJ/kg, which is higher than other biomass derived pyrolysis oils and also significantly higher than that of solid plum seed waste. The maximum liquid yield is found to be 39 wt% of dry biomass feedstock at the temperature range of 520 ^{0} C. The density of the liquid slightly greater than that of diesel. However, the oil from the plum seed may be considered as an important candidate of potential source of alternative fuel, for which further investigation is required.

6.0 REFERENCE

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